European test facilities for solar combisystems and heat stores

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Solar Combisystems

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by

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A technical report of Subtask B

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1 Introduction

Several test institutes have built facilities to test solar combisystems and heat stores of solar combisystems according to the newly developed AC/DC and CCT methods. All these facilities are restricted to systems operating with liquids as heat transfer media. Before start of Task 26, similar test facilities had been built and set in operation at ITW, Germany, SERC, Sweden [1] and TNO, The Netherlands [2]. The design of the newly built test facilities was inspired by these earlier examples.

Unlike the CTSS method, the AC/DC and the CCT methods require an accurate emulation of the collector gain and building load. The most important difference between AC/DC method and CCT method is that, with the CCT method, the building load is calculated by a dynamic (online) simulation of the building whereas with the AC/DC method emulation of the space-heating load is based on a load file. An overview of how the different components are installed, operated and tested with the different test methods is given in Table 1.

Table 1: Overview of components used in different test methods

	CTSS	AC/DC	CCT
Solar collector	standard charge (1)	optionally installed under solar simulator or on-line emulation	on-line emulation
Collector loop	not installed, may be tested separately	optionally installed for testing	installed for testing
Collector pump and controller	not installed, may be tested separately	installed for testing	installed for testing
Auxiliary heater and controller	not installed, not tested	installed for testing (2)	installed for testing
Space heating controller, valve and pump	not installed, may be tested separately	not installed, not tested	installed for testing
Space-heating load	standard discharge (1)	load file	on-line emulation

(1) Collector gain and space-heating load do not need to be precise. Charging and discharging takes place at constant power and flow rates or according to a file.

(2) Preferably, the solar combisystem is tested together with the auxiliary heating normally delivered with the system. In some cases, laboratory heater may be used. The test report always presents system performance of combination of solar combisystem and auxiliary heating.

2 Test facility at ITW, University of Stuttgart

The test facility at ITW consists of four separate modules, i.e. circuits. Two modules are used for charging and two modules are used for discharging of the store. Hence, regarding combistores it is possible to emulate solar heating, auxiliary charging, hot water discharge and space-heating load.

The test sequences are performed automatically, controlled by a PC. The PC is able to communicate with the modules in order to control the inlet temperatures and flow rates to the store. Furthermore, all store inlet and outlet temperatures, volume flow rates and ambient temperature are recorded by the PC.

In every charge and discharge module, several electrical heating elements and a temperature controller are included. The charge and discharge sequences are started and stopped by the PC by switching solenoid valves that are located in the modules. It is also possible to change the flow rates in the circuits by motorised valves controlled by the PC.

The *charge modules* can be used for charging with constant temperature or constant thermal power. Furthermore, it is possible to emulate the solar charging process usually performed by a solar collector. For that purpose, collector parameters and meteorological data can freely be chosen in the PC software running the facility. Technical data of the charging modules (circuits) are:

- Volume flow rate up to a maximum of 1500 litres per hour.
- Heating power up to a maximum of 22 kW.
- Temperature constancy of ± 0.05 K.

The two charging modules are constructed identically; Figure 1 shows one of them.

The *discharge modules* are supplied with cold water from a 750 litres buffer store that is cooled down via a heat exchanger connected to a cooling system being part of the building. Technical data of the discharging modules are:

- Volume flow rate up to a maximum of 1500 litres per hour.
- Heating power up to a maximum of 15 kW.
- Temperature constancy of ± 0.05 K.

The two discharge modules are also constructed identically; Figure 2 is showing one of them.

Figure 1: Charge module at ITW.

Figure 2: Discharge module at ITW.

3 Test facility at SP Swedish National Testing and Research Institute

The test facility at SP also consists of four separate circuits, i.e. two for solar and auxiliary charge and two for domestic hot water and space heating discharge. Tests run fully automatically, controlled again by a PC, just as at ITW.

The two charge and one of the discharge modules contain several electrical heating elements and a temperature controller. Charge and discharge sequences are started and stopped by the PC by switching solenoid valves located either in the modules or in direct connection to the test object. It is also possible to change most of the flow rates in the circuits by motorised valves controlled by the PC.

The *charge modules* can be used for charge with constant temperature or constant thermal power. It is also possible to simulate the charging process of a solar collector. Collector parameters and meteorological data are available in the PC controlling the test facility. Properties of the two charge modules differ in volume flow rate and heating power as follows:

Table 2: Properties of the two charge modules at SP test facilities.

	Auxiliary heating or boiler module	Collector module
Volume flow rate	0.015-3.0 m^3 per hour	0.015-1.3 m^3 per hour
Heating power	30 kW	9 kW
Temperature constancy	± 0.1 K	± 0.1 K

Figures 3 and 4 present the two charge modules.

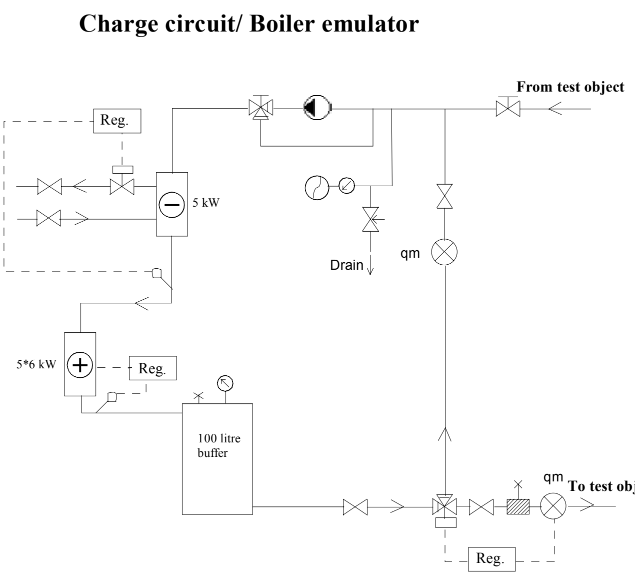

Figure 3: Charge module 1 at SP: auxiliary heating emulator.

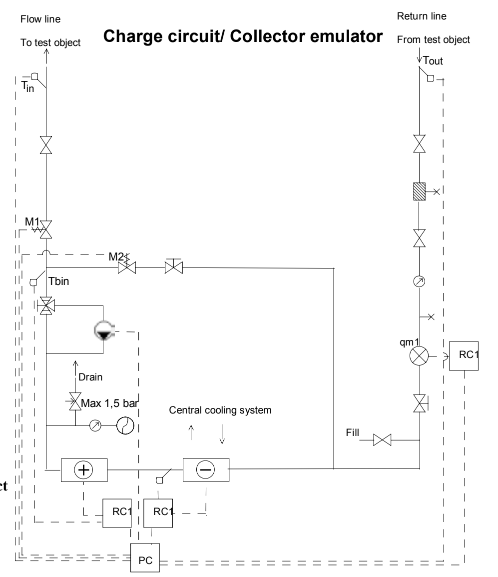

Figure 4: Charge module 2 at SP: solar collector emulator.

The *discharge module* for space-heating load is cooled via a heat exchanger connected to the cooling system of the building. The module for hot water discharge is fed directly from a temperature-controlled domestic hot water circuit. Flowrate is set through opening one of three solenoid valves with pre-adjusted flows. Technical data of both discharge modules have been listed in Table 3.

Table 3: Properties of the two discharge modules at SP test facilities.

	Space-heating load module	Domestic hot water load module
Volume flow rate	0.02 - 3.0 m^3 per hour	0.1 – 1.0 m^3 per hour
Cooling/ Heating power	15/ 12 kW	40 kW
Temperature constancy	± 0.1 K	± 0.2 K

Figure 5 shows one of the discharge modules.

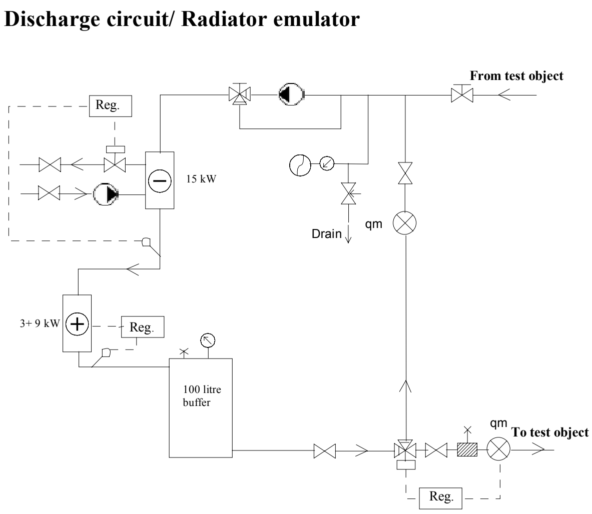

Figure 5: Discharge module.

4 Test facility at CSTB Sophia Antipolis in France

Numerical simulation can take over part of the environment of the system under test. The objective of this is (1) to achieve a flexible test environment in which changes can be implemented rapidly, (2) to test systems under conditions close to reality, (3) to ensure a perfect reproducibility of tests, (4) to evaluate system performance from shorter test sequences and (5) to easily adapt the tests to all types of system configurations.
The test facility for combistores at CSTB is thus divided into a 'real' part, i.e. hydraulic circuits, controlled in real time by the intermediary of a 'software' part. The software part (under Matlab-Simulink) contains modelling and simulation of the environment of the tested system, meteorological data, building, solar collector and hot water draw-off profile, all to be freely programmed.

An interface between hardware and software allows control of inlet temperatures and flow rates according to programmed test sequences or results of simulation of the environment. It is also possible to record on PC all the inputs and outputs of the system necessary for the evaluation, i.e. fluid temperatures, flow rates, ambient temperature and quantity of energy.

The hydraulic part finally allows emulation of the operating conditions of the system under test, as much in supply of heat by solar collector and auxiliary heating as in cold production for hot water draw-off and space heating. The hydraulic part consists of four circuits:

- Two *charge modules* (see Figure 6) supply gas-heated hot water to maintain a constant temperature or to set a variable temperature at the input of the system for studies in dynamic mode. A programmable controller takes care of the charges by managing a system of 3-port valves and mixing bottle to deliver the right temperature and flow rate at the inlet of the system, in accordance with simulation. Technical data of the charge modules are:
  - Volume flow rate up to a maximum of 9 m^3 per hour.
  - Heating power up to a maximum of 50 kW.
  - Uncertainty in the temperature ± 0.05K, in the flow rate ± 0.1%.
  - Stability of the temperature ± 0.2°C, of the flow rate ±0.003kg/s.
- Two *discharge modules* (see Figure 7) use a dry cooler in cascade with a group of compressors (7 to 18°C) for mixing cold and hot water according to the needs. The discharges are controlled by the interface with the programmable controller. Technical data of the discharge modules are:
  - Volume flow rate up to a maximum of 5 and 6 m^3 per hour respectively.
  - Cooling power up to a maximum of 50 kW.
  - Uncertainty in the temperature ± 0.05K, in the flow rate ± 0.1%.
  - Stability of the temperature ± 0.2°C, of the flow rate ±0.003kg/s.

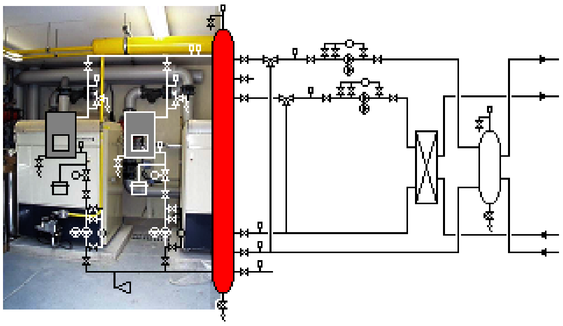

Figure 6: Charge module at CSTB.

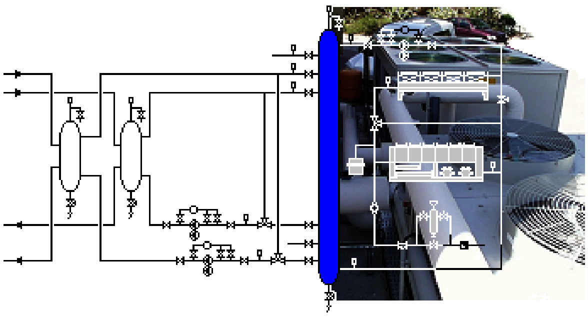

Figure 7: Discharge module at CSTB.

5 Test facility at TNO in The Netherlands

The test facility for solar combistores at TNO again consists of four circuits for charging and discharging the heat store. The facility is combined with that for solar collectors for quality testing. This enables carrying out tests on solar combisystems including collector under the solar simulator; see figure 8.

Additional thermal circuits have been developed for testing combistores. Equipment for hot water draw-off is virtually identical to that in use for DST testing of solar systems, i.e. it is capable to offer constant temperature at the domestic hot water inlet. Heating circuits can simulate auxiliary heating and solar collector, i.e. if the solar simulator is not used or if the collector is too big for the simulator. These thermal circuits allow for independent control of temperature and flow rate by individually controlled heaters and heat exchangers to the central cooling unit. These circuits can supply flow rates upto 0.4 kg/s with heating power of 11 kW. PID controllers coupled to valves and heating elements manage flow and temperature control. Solenoid valves control the activity of the various test circuits. Controllers in the individual circuits get their set points from a PC performing the entire test sequence through a dedicated software programme.

Additional hardware is available to provide the outdoor temperature sensor of the controller of the combisystem with the necessary outdoor temperature during the test. The auxiliary heater in Dutch combisystems is generally built into the unit and provided with gas. For systems without dedicated auxiliary supply, an auxiliary gas-heated system can be provided.

Monitoring of the system under test is carried out by the so-called TNO Mup-das data acquistion system, which is based on Fluke Netdaq dataloggers on LAN network. Software processes for monitoring and control communicate via embedded window processes allowing the software to run on independent PC’s if necessary. Network access is available for remote monitoring the progress of the testing process from the researchers desk.

Figure 8: The solar simulator as part of the TNO test facility for solar combisystems.

6 Test facility at SPF in Rapperswil, Switzerland

Before start of Task 26, SPF only owned a very simple, manually operated test facility for testing solar heat stores. Its conversion into a fully automatic test rig was carried out during the task work.

The SPF indoor test facility (see Figure 9) has been designed for tests according to the CCT method. The outdoor ambient air temperature and the building indoor temperatures are provided by small boxes in which the sensors of the system are located. Collector array and building are emulated using heating and cooling circuits. To date, the test facility can accommodate systems using either a gas- or an oil-fired boiler as an auxiliary heater. Alternatively, a heating circuit emulates the auxiliary heater. Mains water supply is temperature and flow-controlled.

The system components are to be set onto the designated floor area or may be attached to dummy inner walls. The installation area is designed in such a way that the components to be tested are separated from those of the test facility. Before each draw-off there is a rinse phase during which mains water temperature and flow rate are adjusted. During rinsing, the flow stream bypasses the heat store. Additional information about the test facility is given in [3].

Figure 9: Floor installation area. A 25 cm grid drawn on the floor gives an indication of the space requirement from that photograph alone.

7 References

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[2] Amerongen, G.A.H. van and A.C. de Geus. Ontwikkeling STF-testmethode voor het testen van complete zonneverwarmingsinstallaties (Development STF test method for solar combisystems). TNO Building and Construction Research, Delft, The Netherlands, 1990.

[3] Vogelsanger, P. The Concise Cycle Test Method – a Twelve Day System Test, Technical Report IEA SHC Task 26 Combisystems, 2002.